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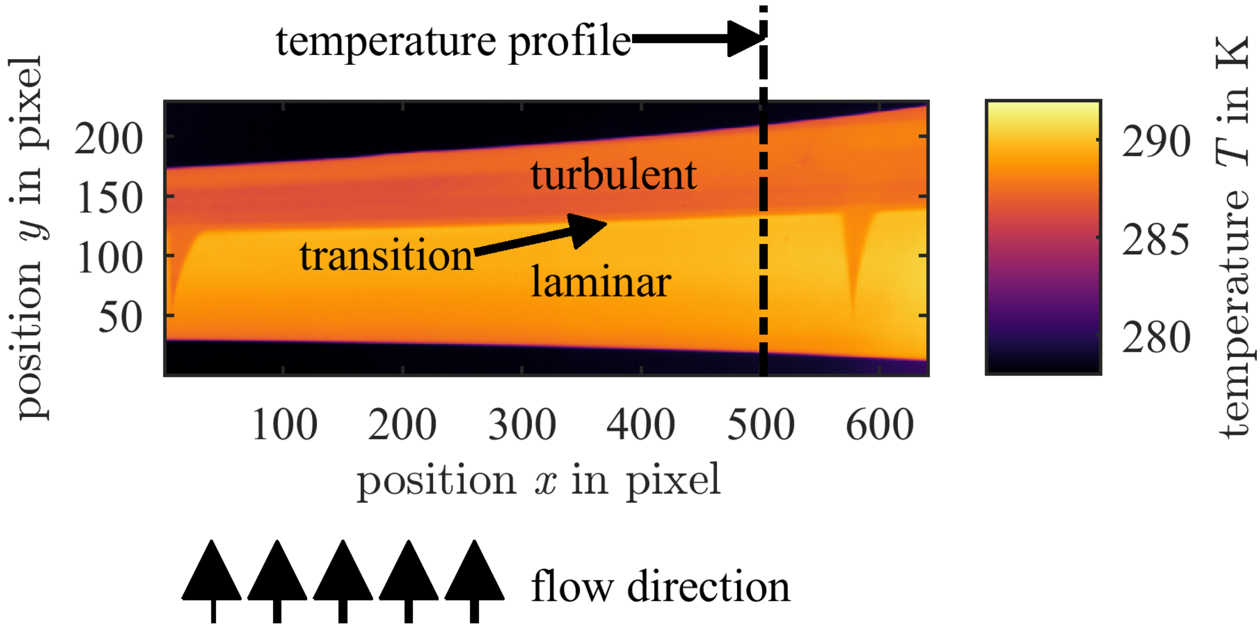
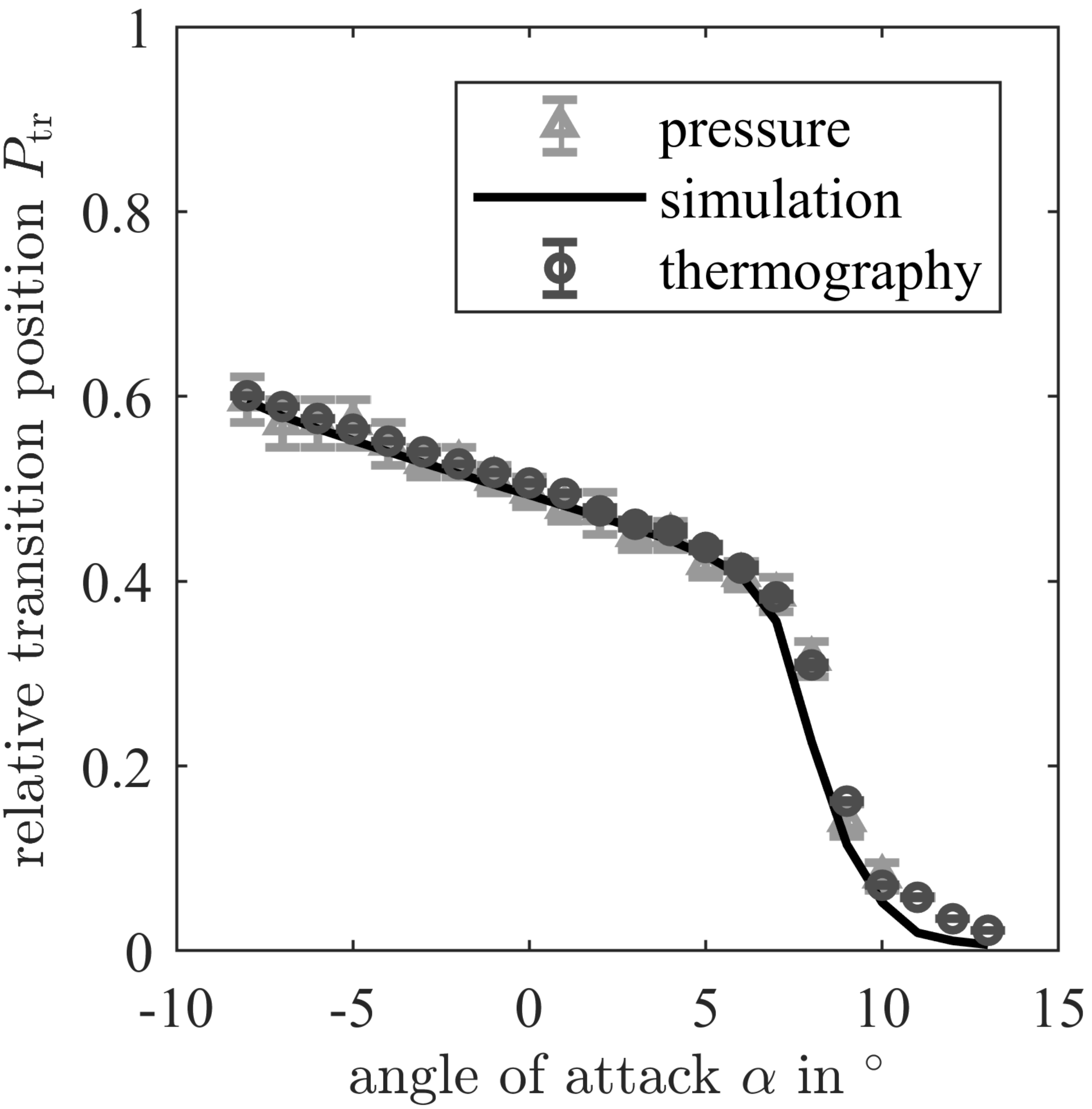
Bremen **I**nstitute for **M**etrology, **A**utomation and **Q**uality Science

(http://www.uni-bremen.de)

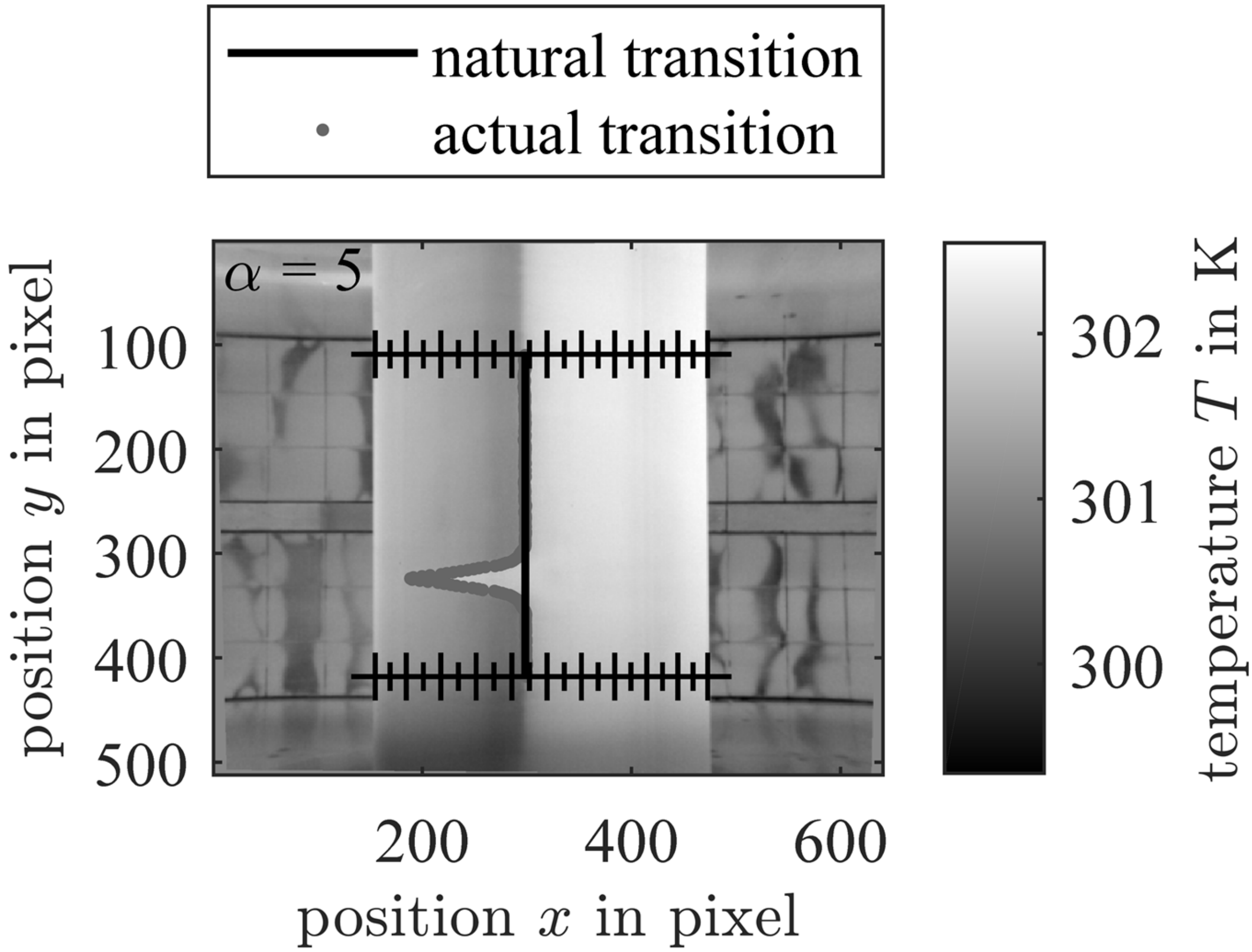
Laboratory for thermographical measurement techniques


BIMAQ


temperature profile
turbulent
transition
laminar
position y in pixel
200
150
100
50
100
200
300
400
500
600
position x in pixel
290
285
280
temperature T in K
flow direction



relative transition position P_{tr}
1
0.8
0.6
0.4
0.2
0
-10
-5
0
5
10
15
angle of attack α in °
pressure
simulation
thermography



For the development of new and the optimization of existing rotor blades for wind turbines, the understanding of the boundary layer flow conditions on the real rotor blade in operation is essential. However, currently used measuring methods require time- and cost-intensive preparation of the rotor blades and influence the measured flow. In contrast, the thermographic flow visualization is a high-resolution non-invasive measuring method which allows the identification and localization of different boundary layer flow regions based on the evaluation of the rotor blade surface temperatures.

At BIMAQ, new measurement and evaluation methods for the thermographic flow visualization are investigated and fundamentally characterized for the investigation of boundary layer flow phenomena on wind energy rotor blades. The acoustically optimized large wind tunnel of Deutsche WindGuard in Bremerhaven, in which laminar flows with speeds of up to 360 km/h and Reynolds numbers of up to 6 million can be generated, is available for basic research. In addition, thermographic measurements can be performed on real wind turbines in operation from distances between 60 m and 500 m. The insights obtained for flow optimization are an important contribution to the expansion of renewable energies.

Research areas

- In process measurements on wind turbines in operation in wind tunnel testing
- Image processing for the
  - Localization of the laminar-turbulent transition
  - Visualization and identification of separated flow
  - Characterization of the contamination/erosion of the rotor blade
  - Identification of structural defects
- Interdependence between flow and macro/microgeometry
- Combination of the thermographic flow visualization with a structural analyses

Measurement service

- Industrial measurement campaigns in cooperation with Deutsche WindGuard Engineering GmbH for the
  - Flow visualization in wind tunnel experiments and on the rotor blades of real wind turbines
  - Functional testing of anti-icing and de-icing systems of wind energy rotor blades in cold climates

Equipment

Thermographic cameras

- Cooled InSb camera (InfraTec ImageIR 8300):
  - Detector size 640 x 512 Pixel
  - Maximum framerate 100 Hz
  - Thermal resolution (NETD) < 0,025 K @ 30 °C
  - Spectral sensitivity 2 – 5 µm
  - Available focal lengths 12 mm, 25 mm, 100 mm 200 mm
- Uncooled microbolometer camera (InfraTec VarioCam hr head):
  - Detector size 640 x 480 Pixel
  - Maximum framerate 50 Hz
  - Thermal resolution (NETD) 0,030 K @ 30 °C
  - Spectral sensitivity 7,5 – 14 µm
  - Available focal lengths 12,5 mm, 30 mm
- Uncooled microbolometer camera (InfraTec PIRuc):
  - Detector size 160 x 120 Pixel
  - Maximum framerate 100 Hz
  - Thermal resolution (NETD) 0,080 K @ 30 °C
  - Spectral sensitivity 7,5 – 13 µm
  - Available focal lengths 5 mm, 10 mm, 36
- Uncooled microbolometer camera (InfraTec mobile E9):
  - Detector size 384 x 288 Pixel
  - Maximum framerate 60 Hz
  - Thermal resolution (NETD) 0,080 K @ 30 °C
  - Spectral sensitivity 8 – 14 µm
  - Available focal lengths 5 mm, 10 mm, 36

Measurement objects

- Wind tunnel models
- Wind turbines

Literature

C. Dollinger, M. Sorg, N. Balaresque, A. Fischer: Measurement uncertainty of IR thermographic flow visualization measurements for transition detection on wind turbines in operation. Experimental Thermal and Fluid Science 97:279-289, 2018.

C. Dollinger, N. Balaresque, M. Sorg, A. Fischer: IR thermographic visualization of flow separation in applications with low thermal contrast. Infrared Physics & Technology 88:254-264, 2018.

C. Dollinger, N. Balaresque, N. Gaudern, D. Gleichauf, M. Sorg, A. Fischer: IR thermographic flow visualization for the quantification of boundary layer flow disturbances due to the leading edge condition. Renewable Energy 138:709-721, 2019.

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